

Discrimination of *Solea solea* nurseries along the French Atlantic coast using otolith elemental signatures

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Introduction

The common sole *Solea solea* (L.) is a commercially important and widely distributed flatfish of the North-East Atlantic. Like most demersal marine fishes around the world, sole stocks suffer from overexploitation. For the Bay of Biscay stock, sole nurseries display differences in terms of quantity (Le Pape *et al.* 2003) and quality (Gilliers *et al.* 2003). *In fine* the measure of the quality of a habitat for juveniles of a particular species is expressed by the contribution to the recruitment into the adult population (Beck *et al.* 2001). Understanding this connectivity between juvenile and adult habitats, *i.e.* evaluating the contribution of each nursery to a single adult stock appears essential in terms of stock management. However, this critical link is still missing for the Bay of Biscay stock.

Otoliths are calcium carbonate structures located in the inner ear of fish. Throughout the life of fish, otoliths grow continuously through accretion forming easily identifiable daily, seasonal and annual marks. During this process, they incorporate chemical elements that indirectly reflect the ambient conditions (e.g. temperature, chemical composition of the water) experienced by the fish. Due to these unique properties, otolith elemental composition analysis has become a powerful tool to determine the nursery origin in adult fish, to discriminate between stocks and sub-populations, and to reconstruct lifetime migration patterns (Campana & Thorold 2001).

The aim of the present study was to determine if the main sole nurseries along the French Atlantic coast could be discriminated using otolith elemental composition analysis of age 0-group juveniles. This study constitutes the first step in evaluating the relative contribution of the different nurseries into the adult stock of the Bay of Biscay.

Material and methods

Fish collection and otolith preparation

0-group sole juveniles were sampled in 6 nurseries (embayed and estuarine) as part of the IFREMER sole nursery survey in the Bay of Biscay (Fig. 1) during September/October 2003 using a beam trawl (2.9 m wide and 0.5 m high, mounted with a 20 mm stretched mesh net at the codend) at 5-20 m depths. Fish were immediately frozen and stored individually at -20°C. Subsequently fish were measured (nearest mm), weighed (nearest 0.01 g) (Table 1) after which the sagittal otoliths were extracted, thoroughly cleaned of adhering tissue and then individually stored in plastic tubes. Only left otoliths were selected for multi-elemental analysis. Otoliths (n=119) were cleaned and decontaminated under a laminar flow positive pressure fume hood by: (1) immersion in ultrapure water, (2) immersion in 0.1% HNO₃ for 1 min (induced less than 2% loss in otolith weight), (3) double immersion in ultrapure water, (4) air dried for 24 hours and (5) stored in decontaminated polypropylene tubes.

Sample analysis

Multi-elemental composition was determined in whole otoliths using solution-based inductively coupled plasma mass spectrometry (ICP-MS, Thermo Element 2). The preparation for analysis was performed in a class 100 (ISO class 5) clean room.

Decontaminated otoliths were weighed on a precision scale to the nearest 0.1 µg (Table 1). Otoliths were dissolved in 15N HNO₃ and diluted proportionally to otolith mass (x1500) in ultrapure water overnight. The following elements were quantified: ⁷Li, ²³Na, ⁴⁰K, ⁴⁴Ca, ⁵⁵Mn, ⁸⁶Sr, ⁸⁷Sr, ⁸⁹Y, ⁹⁰Zr, ⁹¹Zr, ⁹²Zr, ⁹⁴Zr, ⁹⁶Zr, ⁹⁸Zr, ¹⁰⁰Zr, ¹⁰²Zr, ¹⁰⁴Zr, ¹⁰⁶Zr, ¹⁰⁸Zr, ¹¹⁰Zr, ¹¹²Zr, ¹¹⁴Zr, ¹¹⁶Zr, ¹¹⁸Zr, ¹²⁰Zr, ¹²²Zr, ¹²⁴Zr, ¹²⁶Zr, ¹²⁸Zr, ¹³⁰Zr, ¹³²Zr, ¹³⁴Zr, ¹³⁶Zr, ¹³⁸Zr, ¹⁴⁰Zr, ¹⁴²Zr, ¹⁴⁴Zr, ¹⁴⁶Zr, ¹⁴⁸Zr, ¹⁵⁰Zr, ¹⁵²Zr, ¹⁵⁴Zr, ¹⁵⁶Zr, ¹⁵⁸Zr, ¹⁶⁰Zr, ¹⁶²Zr, ¹⁶⁴Zr, ¹⁶⁶Zr, ¹⁶⁸Zr, ¹⁷⁰Zr, ¹⁷²Zr, ¹⁷⁴Zr, ¹⁷⁶Zr, ¹⁷⁸Zr, ¹⁸⁰Zr, ¹⁸²Zr, ¹⁸⁴Zr, ¹⁸⁶Zr, ¹⁸⁸Zr, ¹⁹⁰Zr, ¹⁹²Zr, ¹⁹⁴Zr, ¹⁹⁶Zr, ¹⁹⁸Zr, ²⁰⁰Zr, ²⁰²Zr, ²⁰⁴Zr, ²⁰⁶Zr, ²⁰⁸Zr, ²¹⁰Zr, ²¹²Zr, ²¹⁴Zr, ²¹⁶Zr, ²¹⁸Zr, ²²⁰Zr, ²²²Zr, ²²⁴Zr, ²²⁶Zr, ²²⁸Zr, ²³⁰Zr, ²³²Zr, ²³⁴Zr, ²³⁶Zr, ²³⁸Zr, ²⁴⁰Zr, ²⁴²Zr, ²⁴⁴Zr, ²⁴⁶Zr, ²⁴⁸Zr, ²⁵⁰Zr, ²⁵²Zr, ²⁵⁴Zr, ²⁵⁶Zr, ²⁵⁸Zr, ²⁶⁰Zr, ²⁶²Zr, ²⁶⁴Zr, ²⁶⁶Zr, ²⁶⁸Zr, ²⁷⁰Zr, ²⁷²Zr, ²⁷⁴Zr, ²⁷⁶Zr, ²⁷⁸Zr, ²⁸⁰Zr, ²⁸²Zr, ²⁸⁴Zr, ²⁸⁶Zr, ²⁸⁸Zr, ²⁹⁰Zr, ²⁹²Zr, ²⁹⁴Zr, ²⁹⁶Zr, ²⁹⁸Zr, ³⁰⁰Zr, ³⁰²Zr, ³⁰⁴Zr, ³⁰⁶Zr, ³⁰⁸Zr, ³¹⁰Zr, ³¹²Zr, ³¹⁴Zr, ³¹⁶Zr, ³¹⁸Zr, ³²⁰Zr, ³²²Zr, ³²⁴Zr, ³²⁶Zr, ³²⁸Zr, ³³⁰Zr, ³³²Zr, ³³⁴Zr, ³³⁶Zr, ³³⁸Zr, ³⁴⁰Zr, ³⁴²Zr, ³⁴⁴Zr, ³⁴⁶Zr, ³⁴⁸Zr, 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